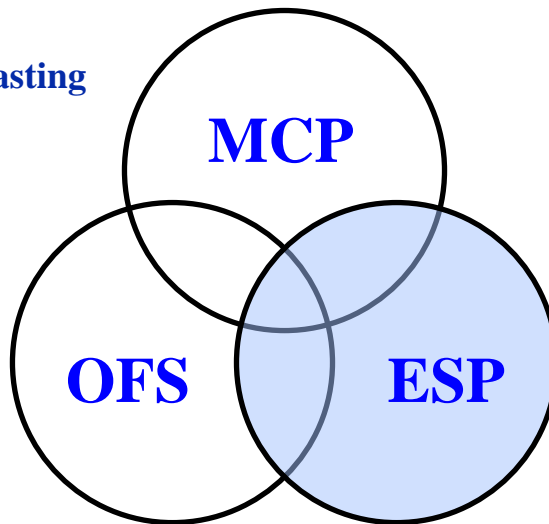


NWSRFS

Ensemble Streamflow Prediction

- Manual Calibration Program (MCP)
- Operational Forecast System (OFS)
- **Ensemble Streamflow Prediction (ESP)**

NWS Workshop on Hydrologic Forecasting
Prague Campus
Czech University of Agriculture
June 20-24, 2005



Ensemble Streamflow Prediction

- NWSRFS models and current states.
- Historical MAPs and MATs from calibration.
- Flexible analysis window.
- Many forecast variables.
- Better performance under extreme conditions.
- Use of weather and climate forecasts.



ESP Uses

- Long range seasonal water supply.
- Spring snowmelt volume forecasts.
- Spring snowmelt peaks.
- Minimum flows for navigation, irrigation, environmental, recreation, etc.
- Experimental Short Term Ensembles
Hours to days



ESP Flexibility

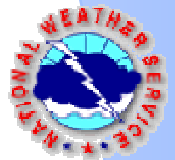
- Time Window
 - Days, Weeks, Months, Seasons
- Variables
 - Volume
 - Mean Discharge
 - Peak Flow
 - Low Flow
 - Days to Peak, Low, or Specified Rate



Key Model States

Initial Conditions Are Important

- Snow Model
 - Liquid and frozen water equivalent
 - Heat content
 - Areal extent
- Soils Model
 - Upper zone moisture content (tension/free)
 - Lower zone moisture content (tension/free)
 - Frozen ground



Accurate Snowpack States

- Real time network consistent with calibration network.
- Quality control temperature and precipitation observations.
- Update snow water equivalent with snow course observations.



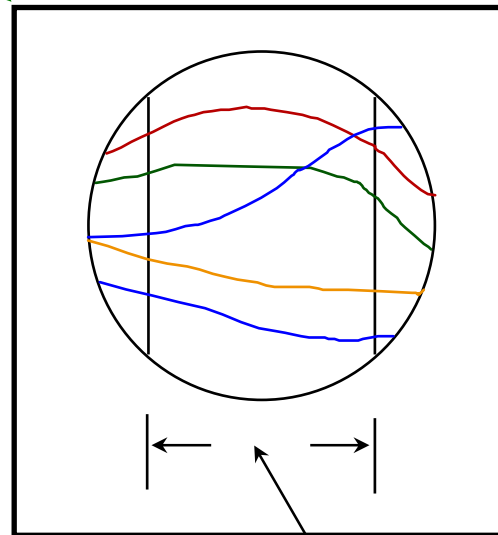
ESP Process

**NWSRFS
Model States**

**NWSRFS
Model
Parameters**

**(Pre-adjusted)
Historical
Temp/Precip**

**Trace Generation
Statistical Analysis**

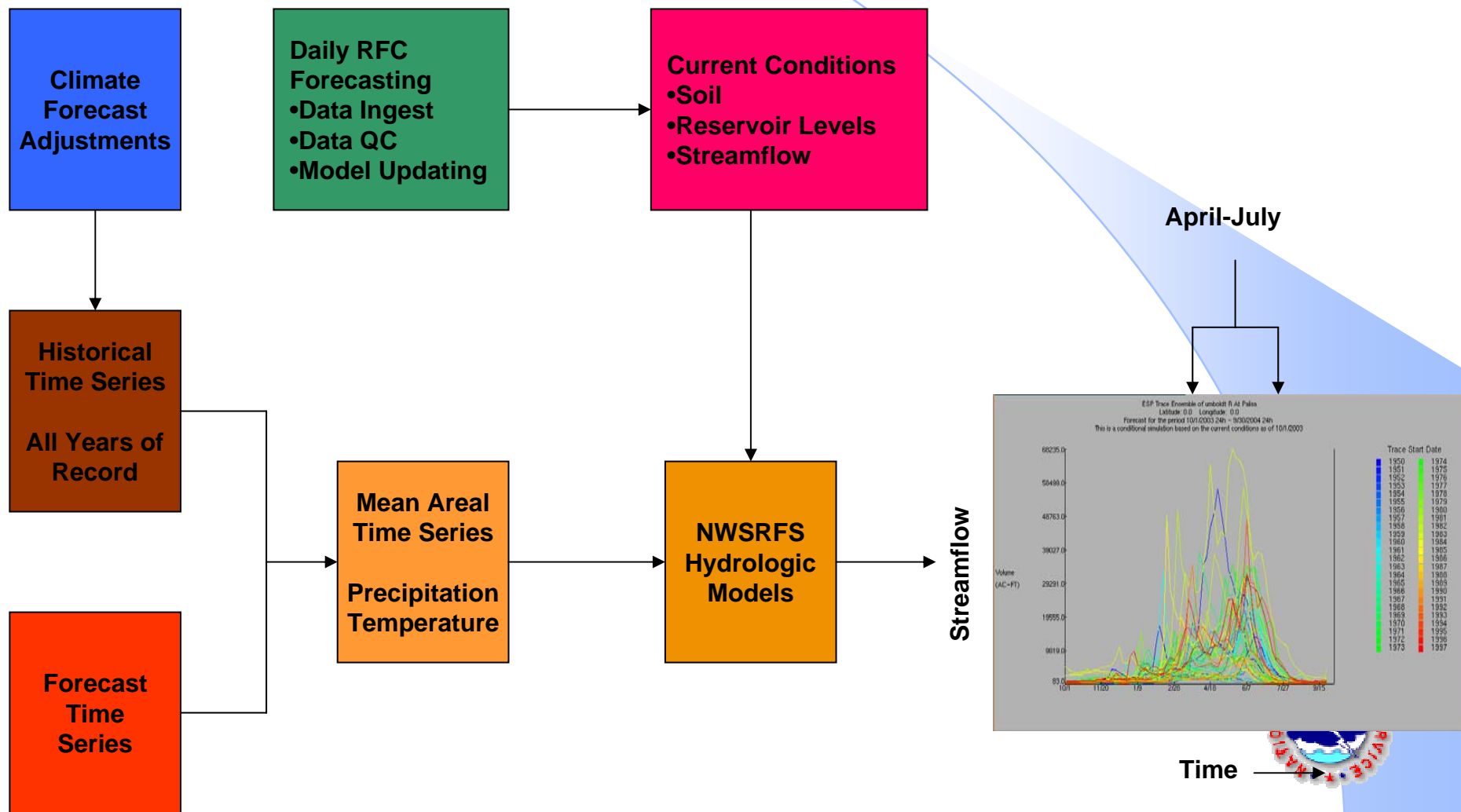


**Analysis
Window**

**Probablistic
Forecast**



Ensemble Streamflow Prediction



Making an Ensemble Forecast Using ESP

Past

Stages

Soil/Snow

States

Blend QPF/QTF

Flow Traces

1971

1972

1973

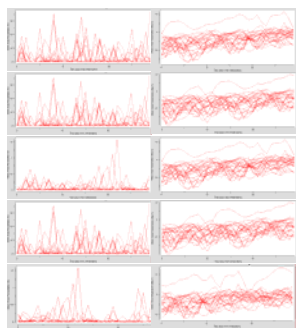
1974

1975

Past

Future Time - >

71
72
73
74
75

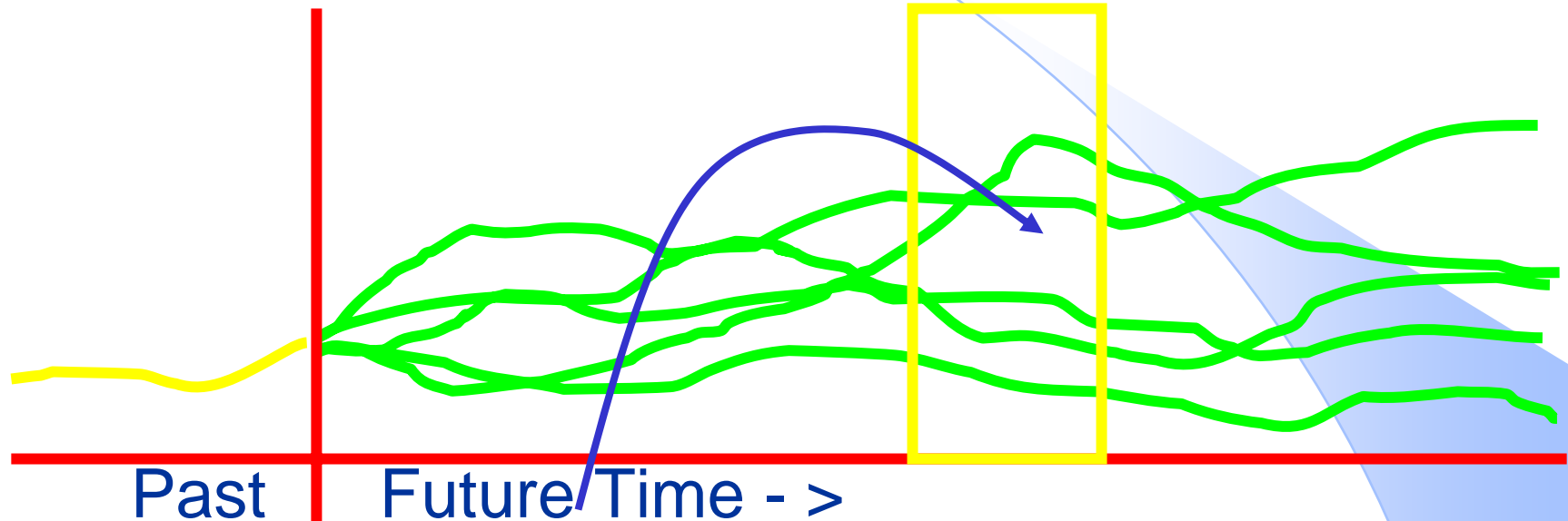


Historical Precip/Temps for Past Years
Creates a Flow for Each Year



Defining Your Time For the Forecast

Window

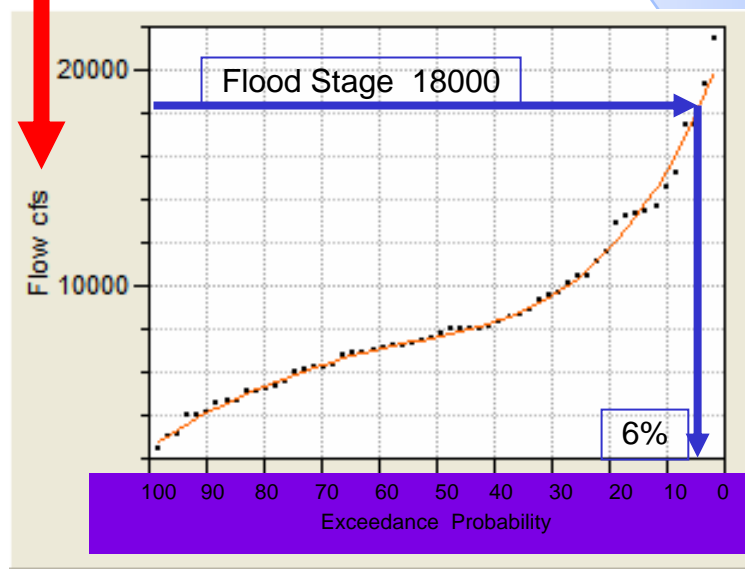
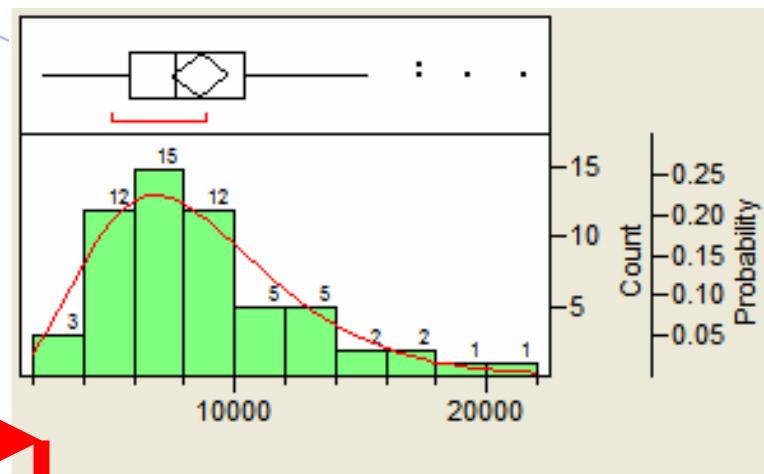


Make a frequency distribution using each ensemble value in the window...and then fit a probability function.

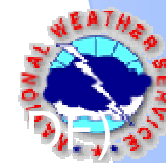


Elementary Probability Concept

21500	8690	6240
19300	8600	6200
17400	8350	6100
17400	8110	5960
15200	8040	5590
14600	8040	5300
13700	8040	5250
13500	8040	5150
13300	7780	5140
13200	7600	4710
12900	7420	4680
11600	7380	4570
11100	7190	4110
10400	7190	4010
10400	7130	4010
10100	6970	3100
9640	6930	2990
9560	6870	2410
9310	6750	
8850	6350	

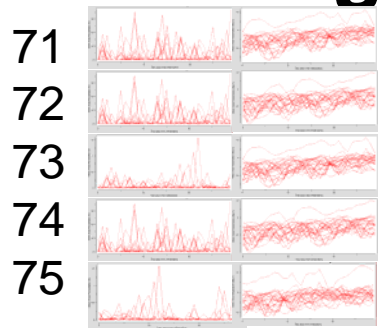


Window

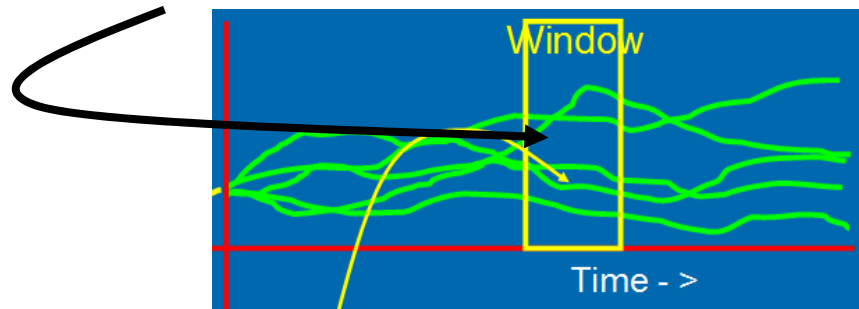


Climate Variability In ESP

Pre -Adjustment Technique
Weight/Modify on Input Side



Post -Adjustment Technique
Weight On Output Side



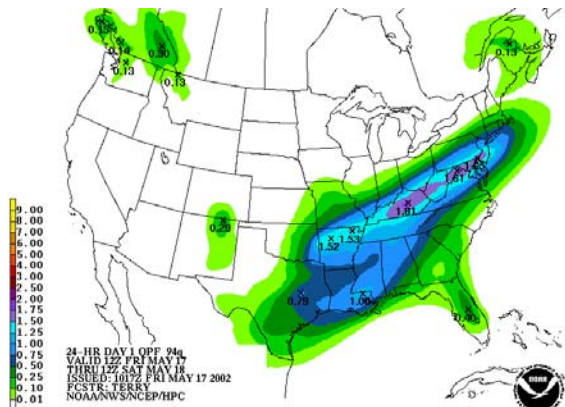
ESP Use of Weather and Climate Forecasts

Historical
MAT and MAP

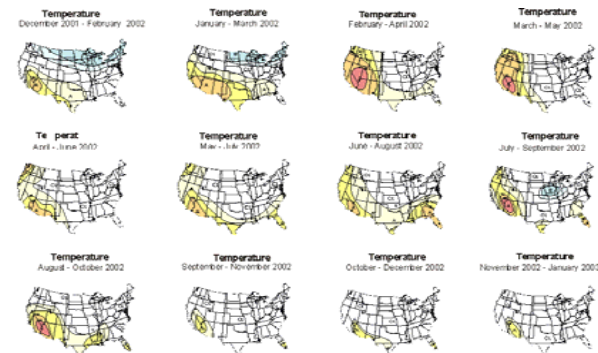
Adjustment
System

Adjusted Historical
MAP and MAT

Weather Forecasts



Climate Forecasts



Release Date: October 17, 2001

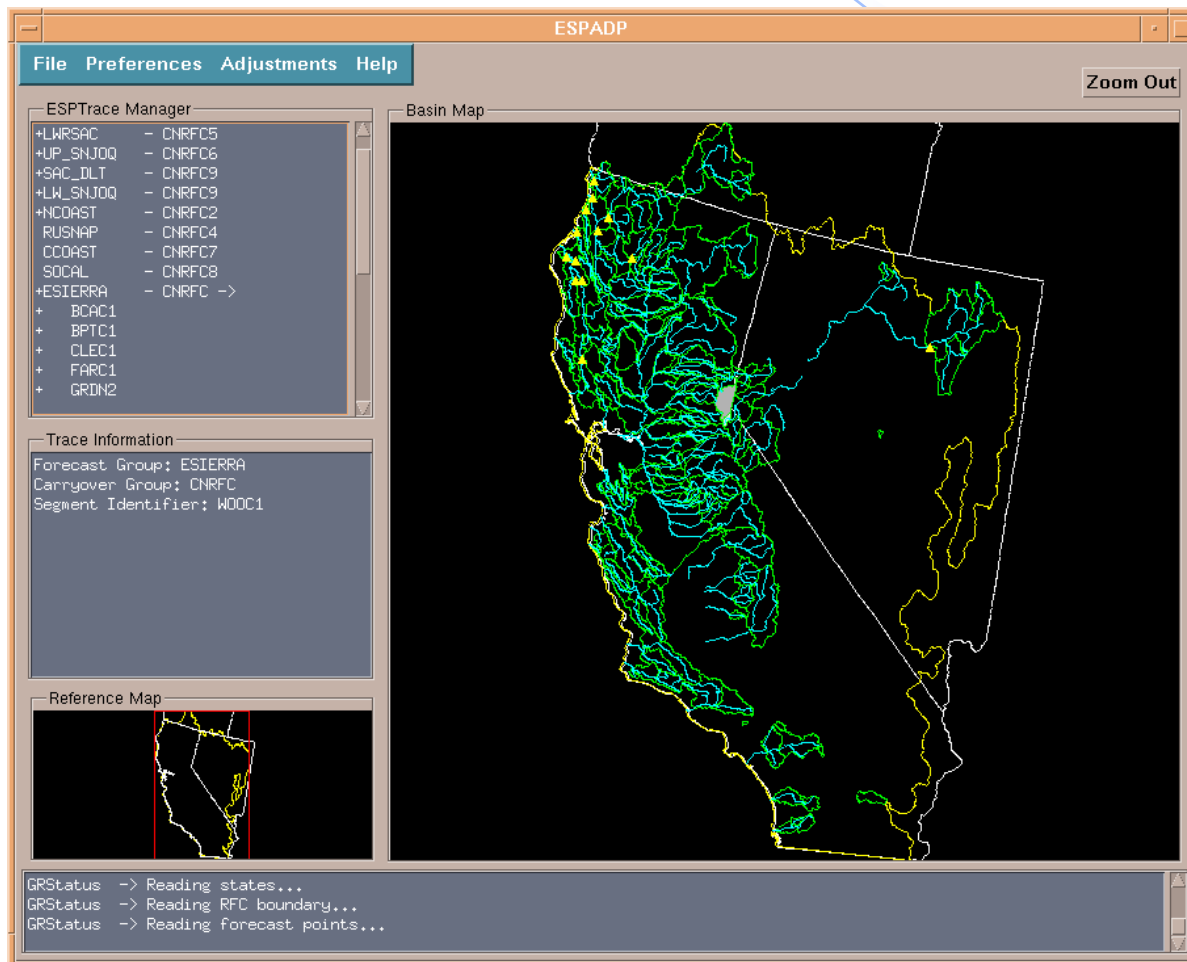


ESP Product Generation

- Generate conditional traces with ESP
- Select product attributes and generate tables and graphics with ESP Analysis and Display Program (ESPADP).



ESPADP - ESP Analysis and Display Program



ESPADP Options

File View YearWeights Y-axis

PlotType Export Display TraceEnsemble

ACCUMULATION SETTINGS

Display Window

Forecast Start Date: 5-17-2002

Begin 5 17 2002

End 7 31 2002

Forecast End Date: 7-31-2002

first accum to:

Daily Accum

☐ None

☐ Inst daily

☐ Mean daily

☒ Total daily

then accum over:

Interval

☐ TSInterval

☐ Monthly

☒ Daily

☐ Window

☐ Weekly

Multiple 5 + -

analyzing:

Output Variable

☐ Max

☒ Sum

☐ NDMX

☐ Min

☐ NDTO

☐ NDMN

☐ Mean

☐ NDIS

☐ < ☒ > 0.00

Apply

Frequency Settings

FREQUENCY SETTINGS

Exceedance Probability Interval Begin Date

Analysis Start Date: 5-17-2002

5 17 2002

Analysis End Date: 7-31-2002



Probability Dist

☐ Empirical

☐ Normal

☒ Log Normal

☐ Wakeby

☐ Weibull

Exceedance Probability Levels (descending)

☐ Default ☒ Manual

1: 0.900 2: 0.500 3: 0.100 4: 5:

6: 7: 8: 9: 10:

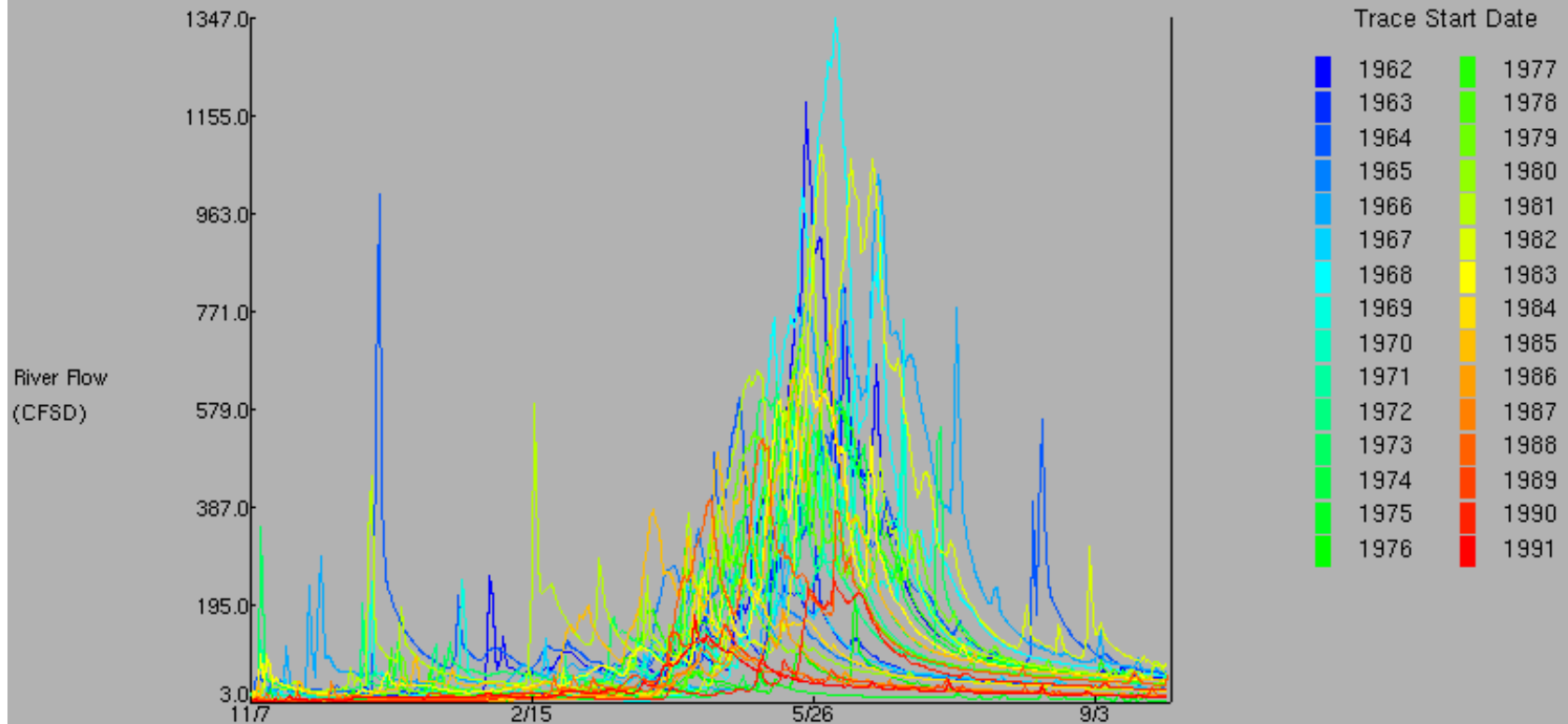
Apply

Accumulation Settings



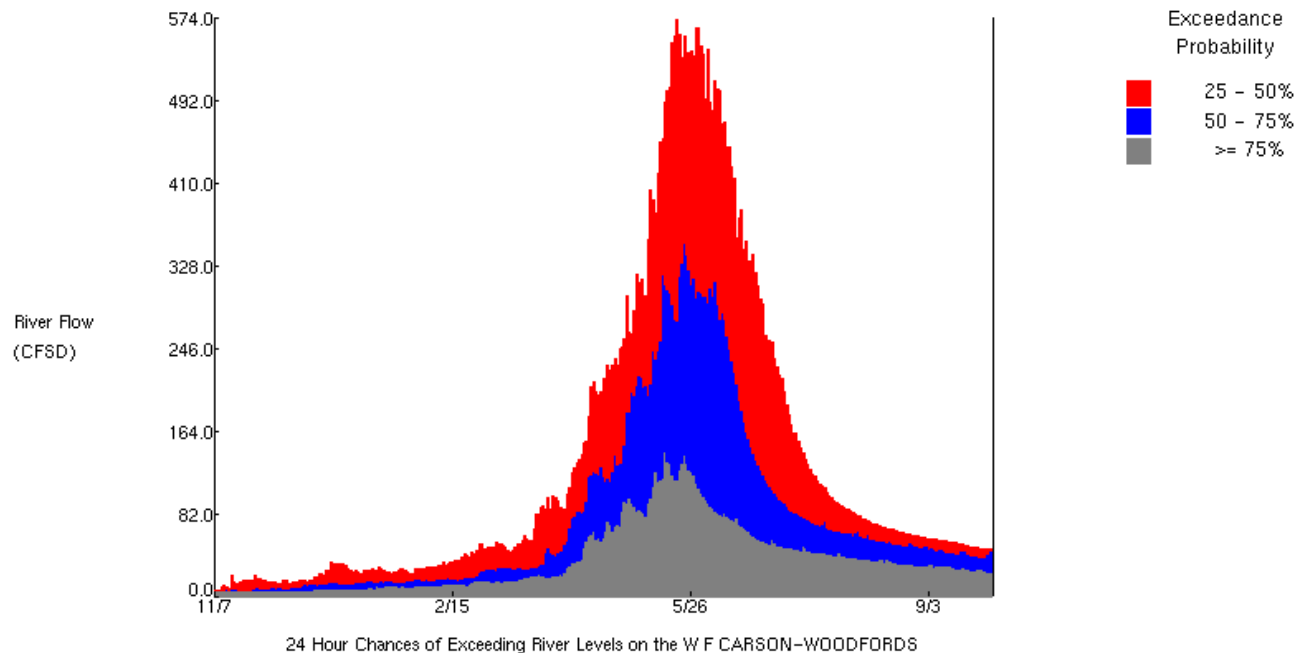
ESP Trace Ensembles

ESP Trace Ensemble of W F CARSON-WOODFORDS
Latitude: 38.8 Longitude: 119.8
Forecast for the period 11/7/2001 24h – 9/29/2002 24h
This is a conditional simulation based on the current conditions as of 11/7/2001



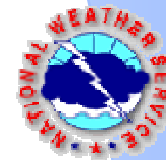
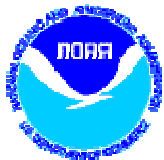
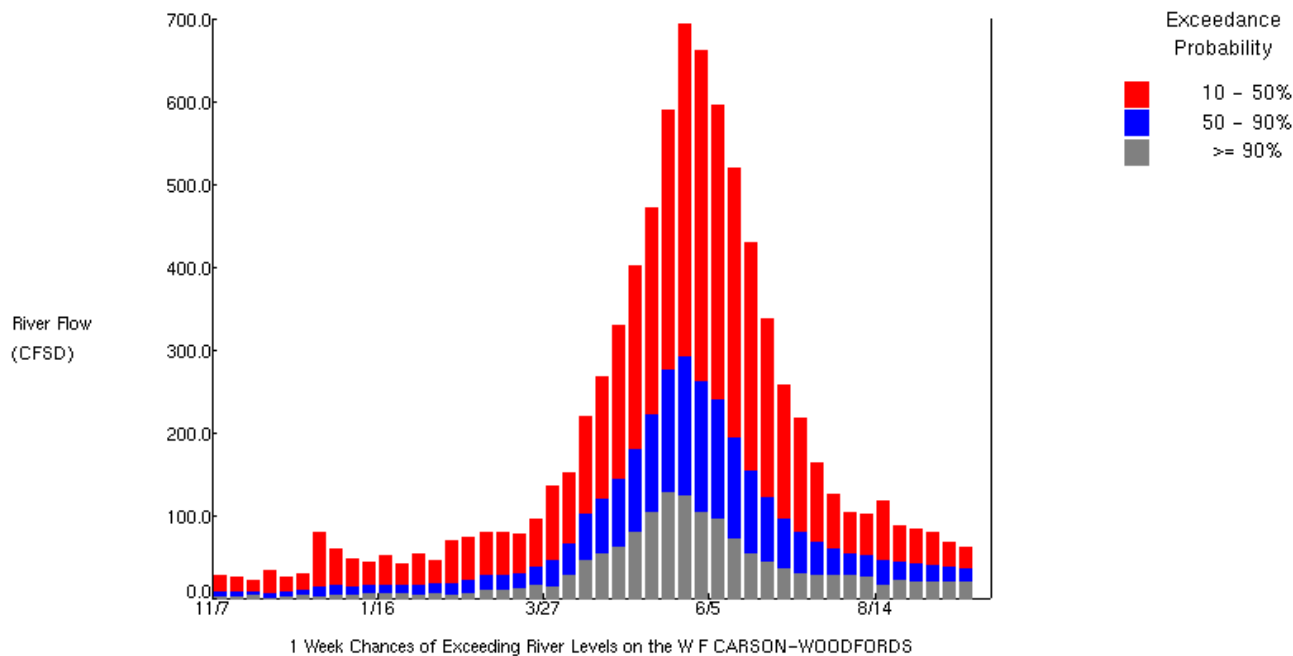
Mean Daily Flows

24 Hour Chances of Exceeding River Levels on the W F CARSON-WOODFORDS
Latitude: 38.8 Longitude: 119.8
Forecast for the period 11/7/2001 24h - 9/29/2002 24h
This is a conditional simulation based on the current conditions as of 11/7/2001



Mean Weekly Flows

1 Week Chances of Exceeding River Levels on the W F CARSON-WOODFORDS
Latitude: 38.8 Longitude: 119.8
Forecast for the period 11/7/2001 - 9/25/2002
This is a conditional simulation based on the current conditions as of 11/7/2001



ESPADP Web Interface

“Allows Customers to Build Their Own Products”

AHPS / ESP Trace Analysis

1 Select a Location:

SPRAGUE RIVER - BEATTY (BTY03)

2 Select an Accumulation Type:

Mean ☒
Minimum ☐
Maximum ☐
Summation ☐

3 Select an Interval:

Day ☒
Week ☐
Month ☐
Entire Period ☐

4 Select a Starting Date:

Month: Jun Day: 16 Year: 2005

5 Select an Ending Date:

Month: Sep Day: 16 Year: 2005

6 Select a Plot Option and Generate:

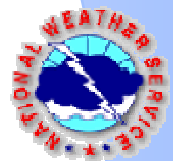
☒ Traces ☐ Probability ☐ Expected Value ☐ Exceedance

Generate a Plot

or Select a Table Option and Generate:

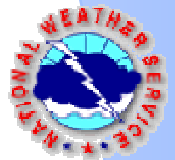
☒ Forecast Info ☐ Quantiles ☐ Flood Quantiles

Generate a Table



Suggestions for Using ESP

- Data quality control is a high priority.
- Be aware of biases or limitations in the model calibration.
- Avoid large changes to model states that cannot be explained by input data errors.
- Remember that ESP does not use runtime MODs.

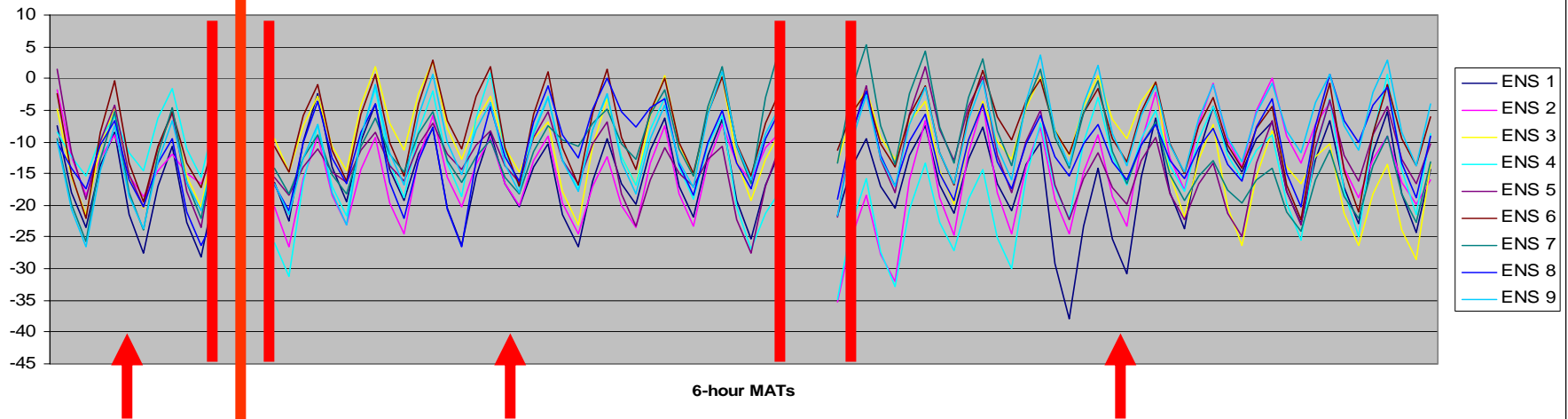


Future use of ESP

- Better use of weather/climate forecasts.
- Implementation of error models.
- Development of short-term techniques.
- Development of regulated forecasts.
 - Reservoir and diversion impacts.
- Interactive use by customers/partners.



Unconnected MAT Ensembles From Three Sources/Models Before Connecting

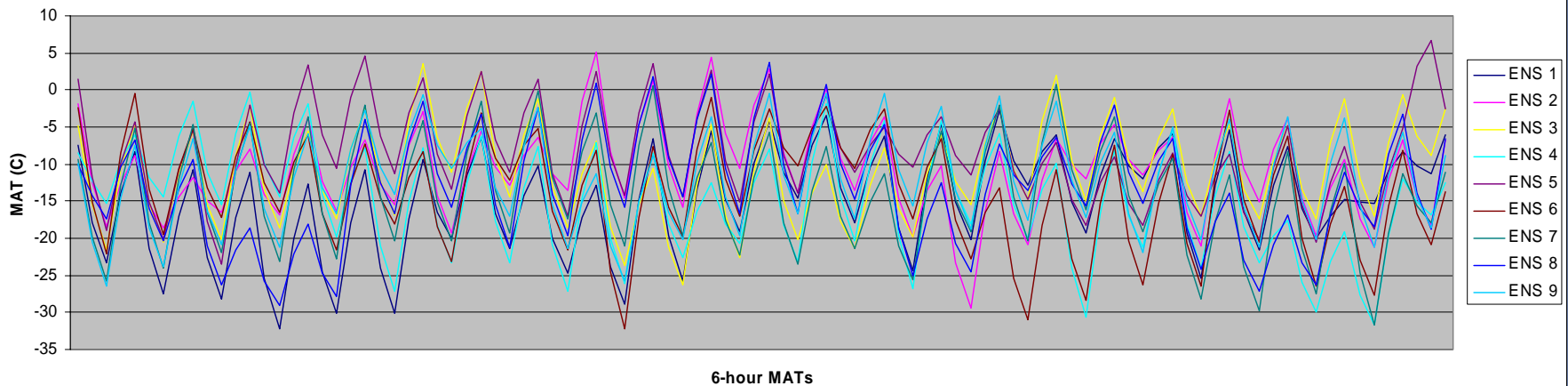


**SHORT TERM
DAY 1-3 HAS**

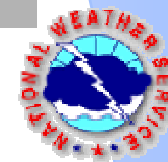
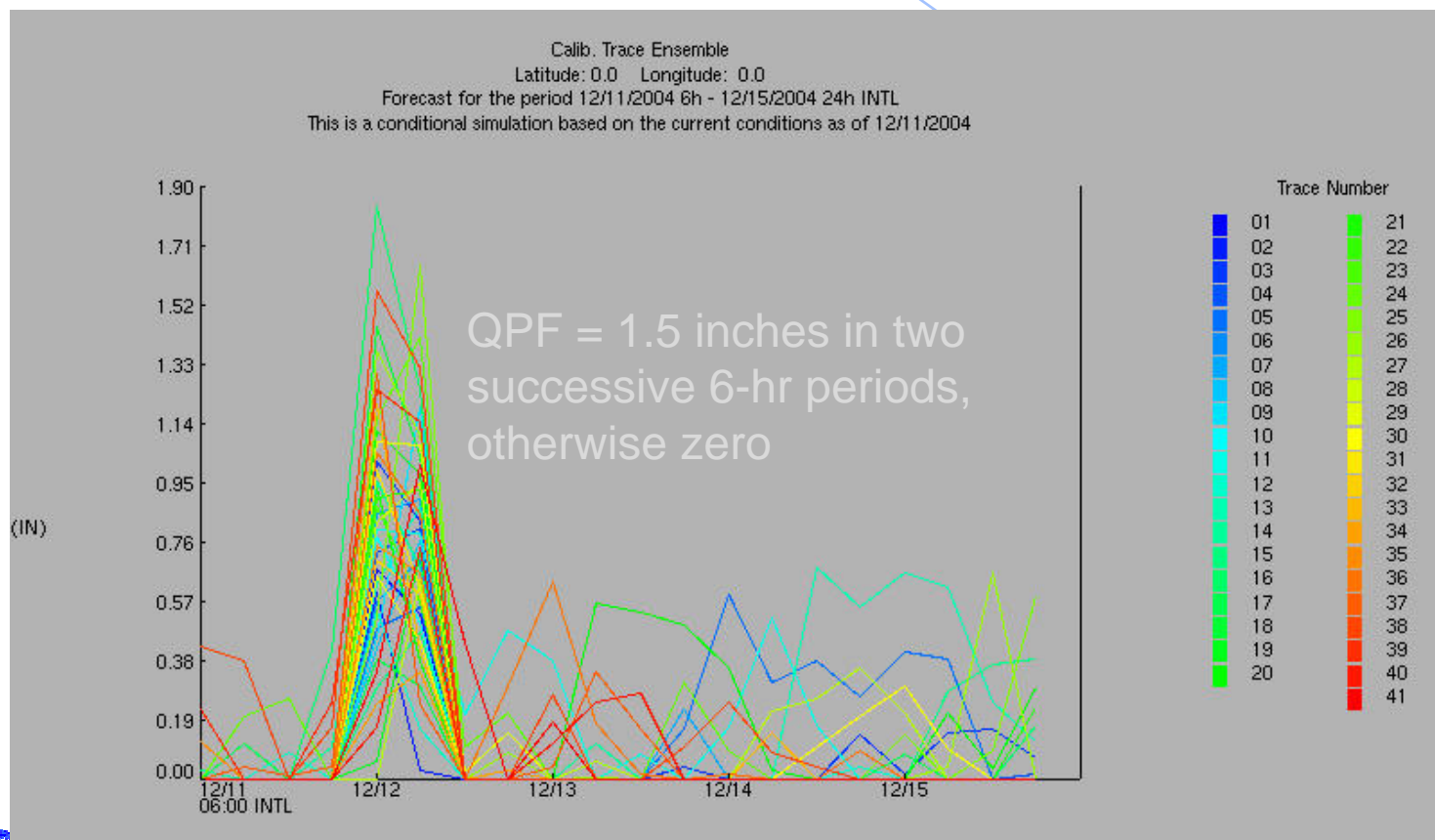
**MEDIUM RANGE DAY 4-14
GFS(MRF)**

**LONG RANGE DAY 15 – 365
CPC PRE-ADJUSTMENT/ OTHER**

Seamless Suite of MAT Ensembles From Three Sources/Models After 'Shuffling'



Short Term 5-day Precipitation Ensembles



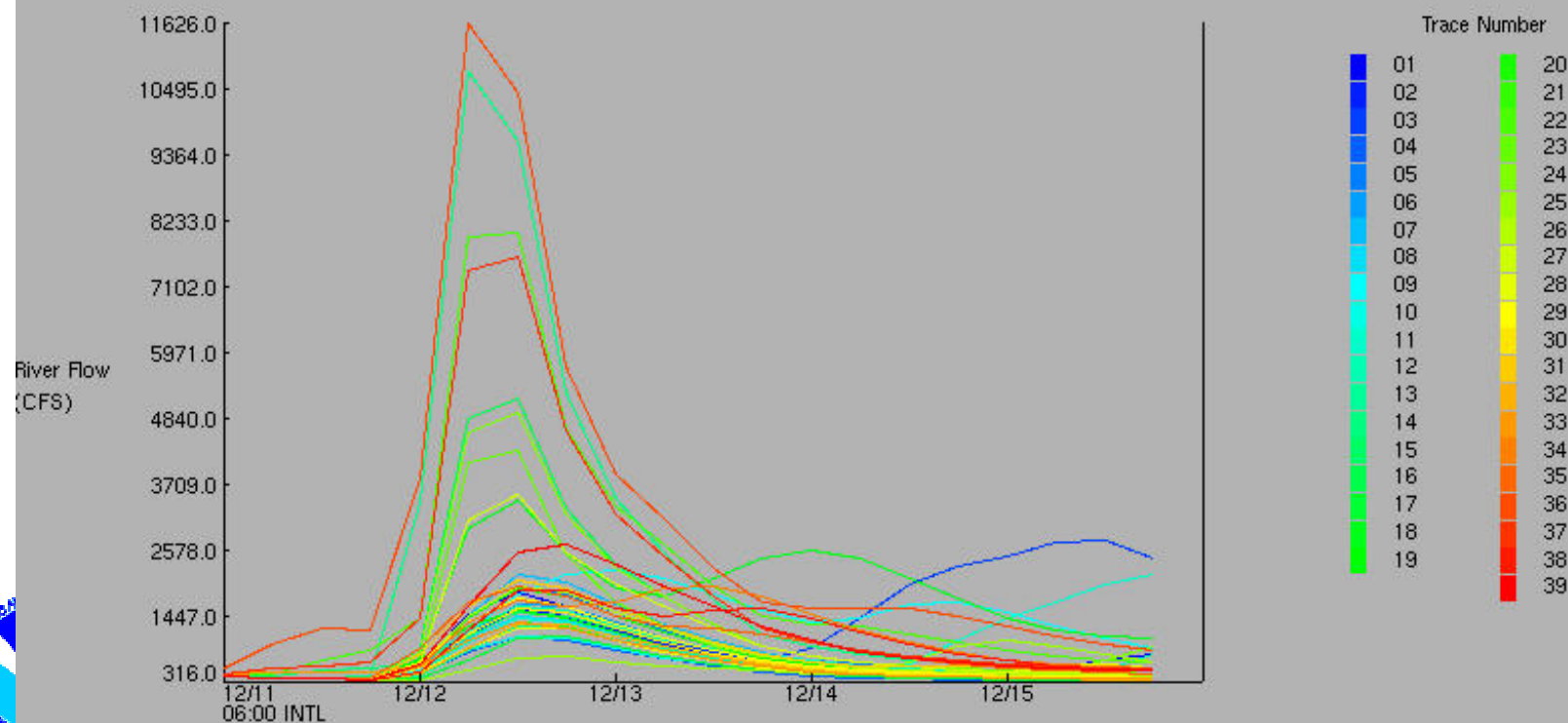
Short Term 5-day Streamflow Ensembles

ESP Trace Ensemble of NF AMERICAN at NF AMERICAN-NF DAM

Latitude: 39.2 Longitude: 120.6

Forecast for the period 12/11/2004 6h - 12/15/2004 24h INTL

This is a conditional simulation based on the current conditions as of 12/11/2004



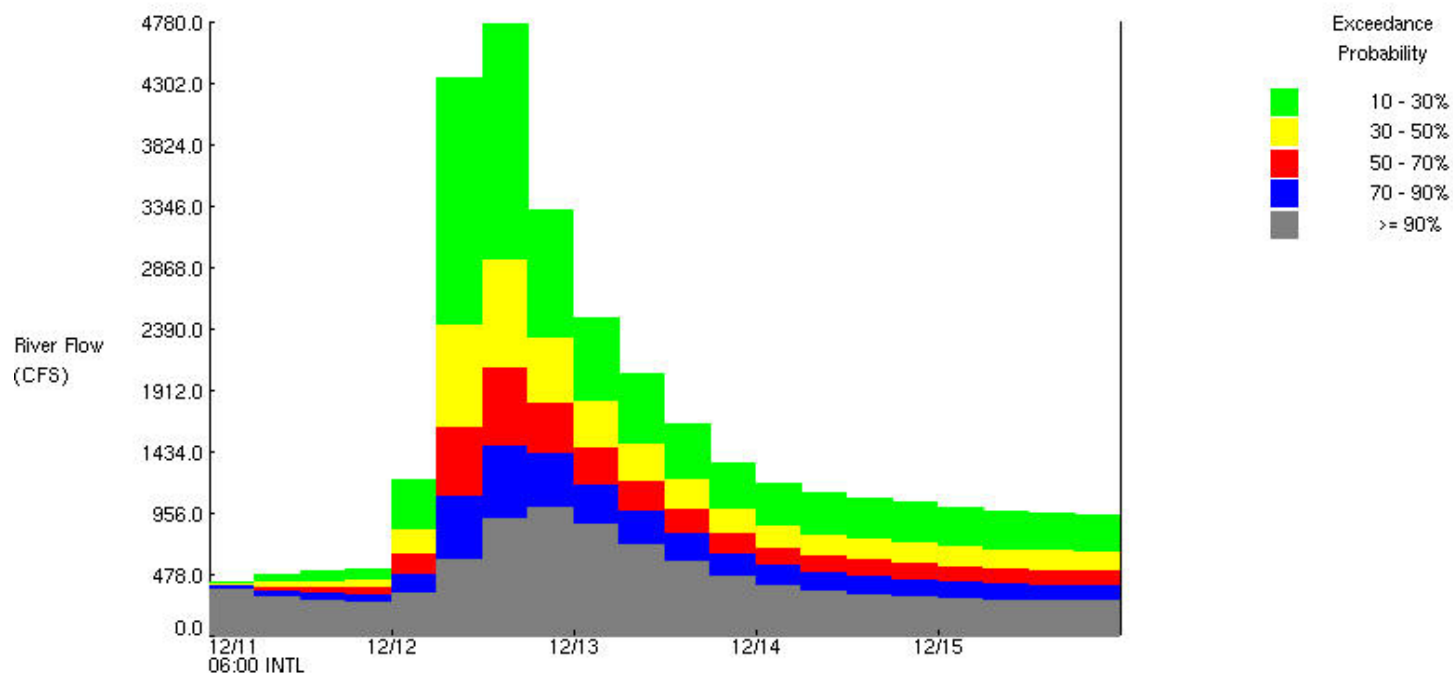
Short Term 5-day Streamflow Forecast Distribution

6 Hour Chances of Exceeding River Levels on the NF AMERICAN at NF AMERICAN-NF DAM

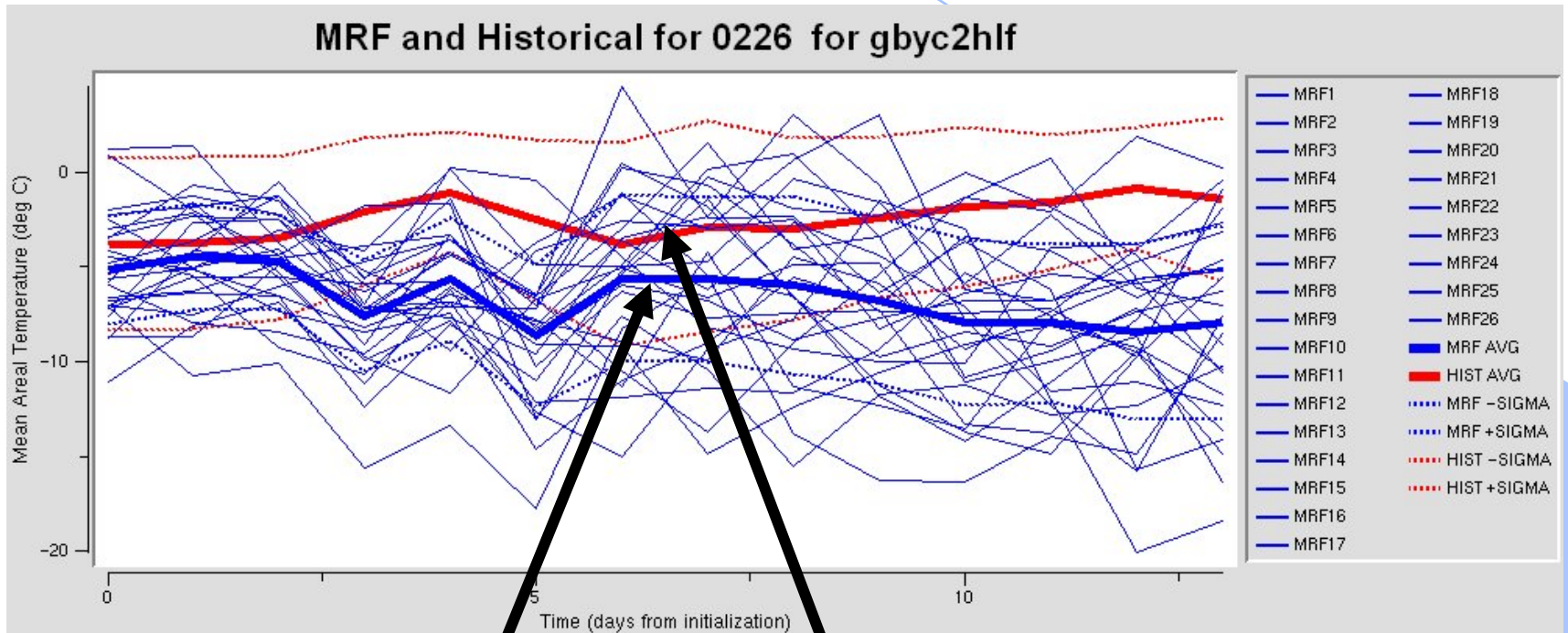
Latitude: 39.2 Longitude: 120.6

Forecast for the period 12/11/2004 6h - 12/15/2004 24h INTL

This is a conditional simulation based on the current conditions as of 12/11/2004



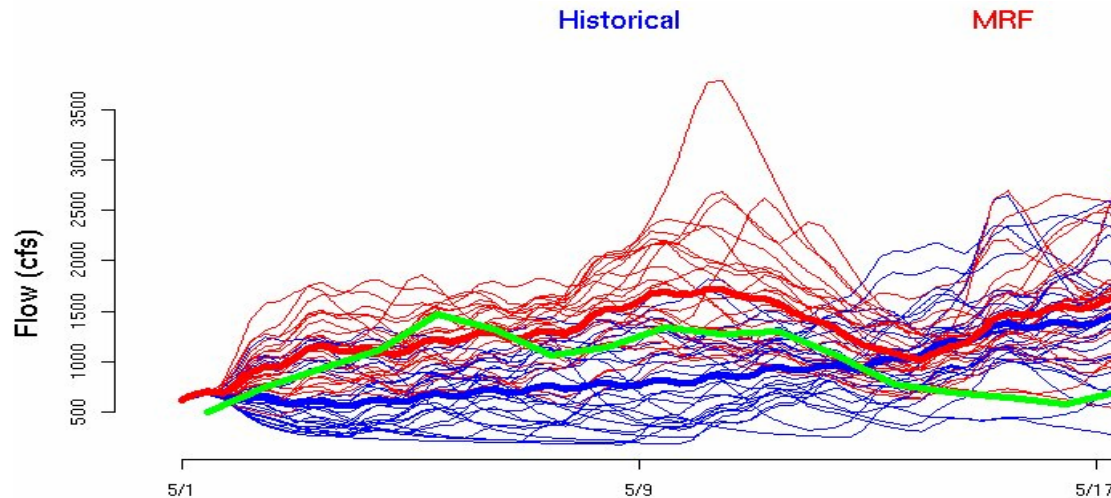
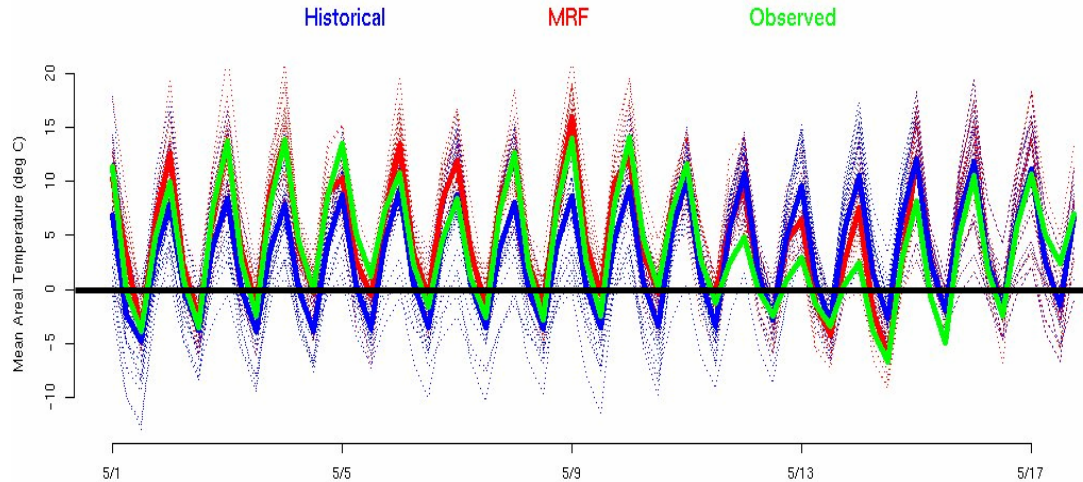
Medium Range Forecasts



MRF is colder than normal in this case.

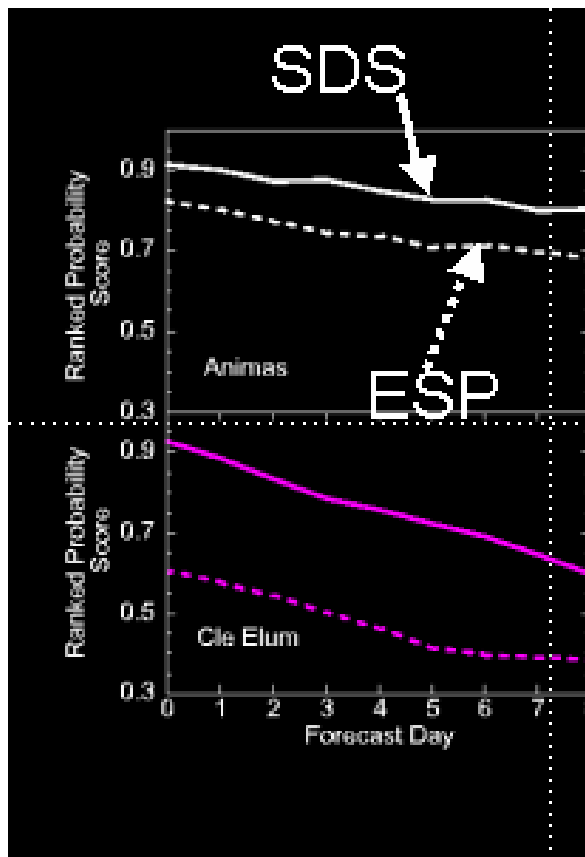


Mean Areal Temperature input into ESP for May 1, 1985 for GBYC2 (middle sub-basin)



Hourly instantaneous flow ensembles are created by ESP and saved. MRF shows higher flows than historical when it is warmer (during the first week). These may be converted into probabilistic forecasts...





An example of the skill in producing streamflow runoff from using temperatures and precipitation downscaled from the MRF vs historical precipitation and temperature (ESP).

It shows by using temperatures from the downscaled MRF in lieu of historical information that streamflow forecasts can be improved.



The End

Ensemble Streamflow Prediction Component (ESP)

